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RESEARCH ARTICLE

A Combined MAGDM-Based Framework Employing EDAS and CRITIC Techniques for Green Building Technology Schemes Evaluation

QIAN LI AND YING LI
Department of Engineering Management, Chengdu Jincheng College, Chengdu, Sichuan 611731, China
Corresponding author: Qian Li (cdjc20230206@126.com)

ABSTRACT The urbanization process in China is rapidly developing, and the scale and development speed of urban area buildings are astonishing. The development of green buildings aims to provide people with a comfortable and healthy living space with minimal resource consumption, achieve harmonious development of the building economy, resources, and environment, and enable them to follow a sustainable development path. When designing green buildings, multiple specialties should be combined, and various technical professions such as architecture, structure, water, heating, and electricity should cooperate and explore together. The green building technology schemes evaluation could be treated as a multiple attribute group decision making (MAGDM) problem. Recently, the EDAS and CRITIC technique was employed to implement MAGDM. Spherical fuzzy sets (SFSs) could express the uncertainty in MAGDM more effectively. In this paper, a novel spherical fuzzy number EDAS (SFN-EDAS) technique based on SFN cosine similarity measure (SFNCSM) and SFN Euclid distance (SFNED) is implemented for managing the MAGDM. Moreover, the CRITIC technique is extended to SFSs to implement the attribute weights based on SFNCSM and SFNED. Finally, SFN-EDAS technique is employed for green building technology schemes evaluation and some comparations to further demonstrate the SFN-EDAS technique.

INDEX TERMS Multiple attribute group decision making (MAGDM), spherical fuzzy sets, EDAS technique, CRITIC technique, green building technology schemes evaluation.

I. INTRODUCTION

The urbanization process in China is rapidly developing, and the scale and development speed of urban area buildings are astonishing [1], [2]. However, in the process of urbanization, we should pay attention to how to achieve a harmonious and unified ecological environment and construction development, and whether it meets the requirements of sustainable resource development [3], [4], [5]. With the development and progress of society, people's living standards are improving year by year. People no longer meet their sensory needs, but pursue higher material and spiritual enjoyment. Many buildings do not consider the harmony with the surrounding environment, and building and environmental issues are increasingly prominent, leading to a pathological development of urban planning. Simply focusing on meeting people's objective material needs while neglecting the harmonious unity of urban development and ecological environment [6], [7], [8]. The ecological environment that relies on survival has had an indelible impact while vigorously developing urban construction. With the development of social economy, people's life philosophy has undergone a certain transformation, and their utilization and development of resources have shifted from excessive use of natural resources to a sustainable development path. As a pillar industry in China, real estate has gradually adjusted its development philosophy during the development process, shifting from an extensive development model to a low-carbon and sustainable development path of green building economy [9], [10], [11]. The development of green buildings aims to minimize resource

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consumption, provide comfortable and healthy living spaces for people, achieve harmonious development of building economy, resources, and environment, and enable them to follow a sustainable development path. Green building is a macro system that should not be idle on individual buildings. It should be considered comprehensively in conjunction with the overall urban planning; When designing green buildings, multiple specialties should also be combined, and various technical professions such as architecture, structure, water, heating, and electricity should cooperate and explore together [12], [13], [14]. The standardization of green turtle architectural design technical solutions is beneficial for designers to solve various problems from an overall perspective, and can intuitively reflect the specific applications of green buildings in various aspects, playing a very helpful role in evaluating green building design stars. The formation of green building design technology solutions can also provide direct assistance to developers, which is beneficial for them to have a direct understanding of the development of the project, and is helpful for the development and control of the project. In the process of developing green buildings, there are many problems at various stages, including deficiencies in design, construction, and management. Green building design, as the foundation of green buildings, plays an indelible role in the development process of green buildings [15], [16], [17]. However, at present, due to the lack of fixed modular management estimates and the lack of unified standards, the design units are basically different in the design stage, Moreover, many design units still have many loopholes in the design process due to limited exposure to green building projects. The purpose of this study is to form a unified design technical solution for the green building design stage, which will bring certain convenience to the evaluation of green building design identification and provide guidance for the subsequent construction and management of green building projects [18], [19], [20].

Due to the complexity of the MADM or MAGDM environment, the ambiguity of human thinking and the uncertainty of things themselves, using accurate numerical values to express the evaluation information of DMs has become an important challenge for MAGDM [21], [22], [23], [24], [25], [26], [27]. The green building technology schemes evaluation could be deemed as a MAGDM [28], [29], [30], [31], [32], [33]. Gundogdu and Kahraman [34] implemented the SFSs which could depict the uncertainty and fuzziness during the green building technology schemes evaluation. Keshavarz Ghorabaee et al. [35] put forward the EDAS technique for MADM. Compared with other decision techniques [36], [37], [38], [39], [40], [41], [42], [43], [44], the obvious advantages of EDAS technique are higher efficiency and smaller computational complexity. More and more decision scholars have implemented the EDAS technique for different fuzzy MAGDM [45], [46], [47], [48], [49], [50], [51]. Unfortunately, we have not been able to detect some useful work for EDAS technique [52] based on based on SFNCSM and SFNED under SFSs in existing decision literatures. Therefore, it is essential to implement the new EDAS based on SFNCSM and SFNED under SFSs. The main goal of this work is to implement the SFN-EDAS technique based on SFNCSM and SFNED which could more efficiently cope with MAGDM. Finally, an empirical application for green building technology schemes evaluation is implemented to show the superiority of SFN-EDAS technique. Therefore, the highlights of this work are outlined: (1) the CRITIC technique is employed to implement the attribute weight values based on SFNCSM and SFNED; (2) the EDAS technique is expanded to SFSs based on SFNCSM and SFNED; (3) a novel SFN-EDAS technique based on SFNCSM and SFNED is implemented for MAGDM; (4) an empirical example for green building technology schemes evaluation and some comparative analysis are implemented to verify the SFN-EDAS technique.

The reminder framework of this paper is implemented. The SFSs is implemented in Sect. II. The SFN-EDAS technique is implemented for MAGDM issue in section III. An empirical example for green building technology schemes evaluation and some comparative analysis is employed to verify the SFN-EDAS technique in Sect. IV. The conclusion is implemented in Sect. V.

II. PRELIMINARIES

Gundogdu and Kahraman [34] implemented the SFSs.

Definition 1 ([34]): The SFSs CC in Θ is implemented:

$$CC = \{(\theta, CT(\theta), CI(\theta), CF(\theta)) | \theta \in \Theta\} \tag{1}$$

where $CT(\theta), CI(\theta), CF(\theta)$ is the truth-membership, indeterminacy-membership and falsity-membership, $CT(\theta), CI(\theta), CF(\theta) \in [0, 1]$ and satisfies $0 \leq CT^2(\theta)+CI^2(\theta)+CF^2(\theta) \leq 1$.

The spherical fuzzy number (SFN) is implemented as $CC = (CT, CI, CF)$, where $CT, CI, CF \in [0, 1]$, and $0 \leq CT^2 + CI^2 + CF^2 \leq 1$.

Definition 2 ([34], [54]): Let $CA = (CT_A, CI_A, CF_A)$ and $CB = (CT_B, CI_B, CF_B)$ be SFNs, the basic operations are implemented:

(1) $CA \oplus CB = (CT_A + CT_B - CT_A CT_B, CI_A CI_B, CF_A CF_B)$;
(2) $CA \otimes CB = (CT_A CT_B, CI_A + CI_B - CI_A CI_B, CF_A + CF_B - CF_A CF_B)$;
(3) $\xi CA = \left(1 - (1 - CT_A)^{\xi}, (CI_A)^{\xi}, (CF_A)^{\xi}\right), \xi > 0$;
(4) $(CA)^{\xi} = \left((CT_A)^{\xi}, (CI_A)^{\xi}, 1 - (1 - CF_A)^{\xi}\right), \xi > 0$.

Definition 3 ([34]): Let $CA = (CT_A, CI_A, CF_A)$, the score value is implemented:

$$CSV(CA) = (CT_A - CI_A)^2 - (CF_A - CI_A)^2, \quad CSV(CA) \in [0, 1]. \tag{2}$$

Definition 4 ([34]): Let $CA = (CT_A, CI_A, CF_A)$, the accuracy value is implemented:

$$CAV(CA) = (CT_A)^2 + (CT_A)^2 + (CF_A)^2, \quad CAV(CA) \in [0, 1]. \tag{3}$$

Gundogdu and Kahraman [34] implemented the order for SFNs.

Definition 5 ([34]): Let $CA = (CT_A, CI_A, CF_A)$ and $CB = (CT_B, CI_B, CF_B)$ be two implemented SFNs, let $CSV(CA) = (CT_A - CI_A)^2 - (CF_A - CI_A)^2$ and $CSV(CB) = (CT_B - CI_B)^2 - (CF_B - CI_B)^2$, and let $CAV(CA) = (CT_A)^2 + (CT_A)^2 + (CF_A)^2$ and $CAV(CB) = (CT_B)^2 + (CT_B)^2 + (CF_B)^2$, respectively, then if $CSV(CA) < CSV(CB)$, we have $CA < CB$; if $CSV(CA) = CSV(CB)$, we have (1) if $CAV(CA) = CAV(CB)$, we have $CA = CB$; (2) if $CAV(CA) < CAV(CB)$, we have $CA < CB$.

Definition 6 ([55], [56]): Let $CA = (CT_A, CI_A, CF_A)$ and $CB = (CT_B, CI_B, CF_B)$, then the SFN cosine similarity measure (SFNCSM) between $CA = (CT_A, CI_A, CF_A)$ and $CB = (CT_B, CI_B, CF_B)$ is implemented:

$$SFNCSM(DA, DB) = \frac{CT_A \times CT_B + CI_A \times CI_B + CF_A \times CF_B}{\left(\begin{array}{c}\sqrt{(CT_A)^2 + (CI_A)^2 + (CF_A)^2}\cdot \\ \sqrt{(CT_B)^2 + (CI_B)^2 + (CF_B)^2}\end{array}\right)}, \quad SFNCSM(CA, CB) \in [0, 1], \tag{4}$$

Definition 7 ([55], [56]): Let $CA = (CT_A, CI_A, CF_A)$ and $CB = (CT_B, CI_B, CF_B)$, then the SFN Euclid distance between $CA = (CT_A, CI_A, CF_A)$ and $CB = (CT_B, CI_B, CF_B)$ is implemented:

$$SFNED(CA, CB) = \sqrt{\frac{1}{2}\left(\left|CT_A^2 - CT_B^2\right|^2 + \left|CI_A^2 - CI_B^2\right|^2 + \left|CF_A^2 - CF_B^2\right|^2\right)} \tag{5}$$

The SFNWA technique is implemented.

Definition 8 ([34]): Let $CA_j = (CT_j, CI_j, CF_j)$ $(j = 1, 2, \cdots, n)$ be a family of SFNs, the SFNWA technique is implemented:

$$\mathrm{SFNWA}_{c\omega}(CA_1, CA_2, \cdots, CA_n) = \overset{n}{\underset{j=1}{\oplus}} (c\omega_j CA_j) = \left(\begin{array}{c}\sqrt{1 - \prod_{j=1}^{n}(1 - CT_j^2)^{c\omega_j}}, \\ \sqrt{\prod_{j=1}^{n}(1 - CT_j^2)^{c\omega_j} - \prod_{j=1}^{n}(1 - CT_j^2 - CI_j^2)^{c\omega_j}}, \\ \prod_{j=1}^{n}(CF_j)^{c\omega_j},\end{array}\right) \tag{6}$$

where $c\omega = (c\omega_1, c\omega_2, \ldots, c\omega_n)^T$ be the weight information of CA_j $(j = 1, 2, \ldots, n)$ and $c\omega_j > 0$, $\sum_{j=1}^{n} c\omega_j = 1$.

III. EDAS TECHNIQUE FOR MAGDM WITH SFNS

Then, SFN-EDAS technique is designed for MAGDM. Let $CA = \{CA_1, CA_2, \ldots, CA_m\}$ be alternatives. Let $CG = \{CG_1, CG_2, \ldots, CG_n\}$ be attributes, $c\omega = (c\omega_1, c\omega_2, \ldots, c\omega_n)$ be weight of CG_j, where $c\omega_j \in [0, 1]$, $\sum_{j=1}^{n} c\omega_j = 1$. Assume$CD = \{CD_1, CD_2, \ldots, CD_l\}$ be DMs with weight values of $cw = \{cw_1, cw_2, \ldots, cw_l\}$, where $cw_k \in [0, 1]$, $\sum_{k=1}^{l} cw_k = 1$. And $CC^{(k)} = \left(CC_{ij}^k\right)_{m\times n} = \left(CT_{ij}^k, CI_{ij}^k, CF_{ij}^k\right)_{m\times n}$ is the overall SFN matrix. Then, the calculating steps are implemented.

Step 1. Construct the DM's SFN-matrix $CC^{(k)} = \left(CC_{ij}^k\right)_{m\times n} = \left(CT_{ij}^k, CI_{ij}^k, CF_{ij}^k\right)_{m\times n}$ and implement the overall SFN-matrix $CC = \left(CC_{ij}\right)_{m\times n}$ through employing the SFNWA technique (7)–(9), as shown at the bottom of the next page.

Step 2. Normalize the $CC = \left(CC_{ij}\right)_{m\times n}$ to $NCC = \left[NCC_{ij}\right]_{m\times n}$.

$$NCC_{ij} = \left(NCT_{ij}, NCI_{ij}, NCF_{ij}\right) = \begin{cases}\left(CT_{ij}, CI_{ij}, CF_{ij}\right), & CZ_j \text{ is a benefit criterion} \\ \left(CF_{ij}, CI_{ij}, CT_{ij}\right), & CZ_j \text{ is acost criterion}\end{cases} \tag{10}$$

Step 3. Implement the SFN average decision solution (SFNADS).

$$SFNADS = \left[SFNADS_j\right]_{1\times n} = \left[\frac{\sum_{i=1}^{m} NCC_{ij}}{m}\right]_{1\times n} \tag{11}$$

$$\left[SFNADS_j\right]_{1\times n} = \left[\frac{\sum_{i=1}^{m} NCC_{ij}}{m}\right]_{1\times n} \times \left(\begin{array}{c}\sqrt{1 - \prod_{i=1}^{m}(1 - NCT_{ij}^2)^{1/m}}, \\ \sqrt{\prod_{i=1}^{m}(1 - NCT_{ij}^2)^{1/m} - \prod_{i=1}^{m}(1 - NCT_{ij}^2 - NCI_{ij}^2)^{1/m}}, \\ \prod_{i=1}^{m}(NCF_{ij})^{1/m},\end{array}\right) \tag{12}$$

Step 4. Implement the SFN positive ideal decision solution (SFNPIDS) and SFN negative ideal decision solution (SFNNIDS):

$$SFNPIVS_j = \left(NCT_j^+, NCI_j^+, NCF_j^+\right) \tag{13}$$

$$SFNNIDS_j = \left(NCT_j^-, NCI_j^-, NCF_j^-\right) \tag{14}$$

$$SV\left(SFNPIDS_j\right) = \max_i SV\left(NCT_{ij}, NCI_{ij}, NCF_{ij}\right) \tag{15}$$

$$SV\left(SFNNIDS_j\right) = \min_i SV\left(NCT_{ij}, NCI_{ij}, NCF_{ij}\right) \tag{16}$$

Step 5. Implement the weight information with CRITIC.

The CRITIC [53] is utilized to have the weight information.

(1) The SFN correlation coefficient (SFNCC) is implemented (17), as shown at the bottom of the next page.

where

$$\chi\left(NCC_j\right)=\frac{1}{2m}\sum_{i=1}^{m}\left(SFNCSM\left(NCC_{ij},SFNPIDS_j\right)+SFNED\left(NHH_{ij},SFNNIDS_j\right)\right),$$
$$\chi\left(NCC_t\right)=\frac{1}{2m}\sum_{i=1}^{m}\left(SFNCSM\left(NCC_{it},SFNPIDS_t\right)+SFNED\left(NCC_{it},SFNNIDS_t\right)\right),$$
$$\chi\left(NCC_{ij}\right)=\frac{1}{2}\left(SFNCSM\left(NCC_{ij},SFNPIDS_j\right)+SFNED\left(NCC_{ij},SFNNIDS_j\right)\right),$$
$$\chi\left(NCC_{it}\right)=\frac{1}{2}\left(SFNCSM\left(NCC_{it},SFNPIDS_t\right)+SFNED\left(NCC_{it},SFNNIDS_t\right)\right).$$

(2) Implement the SFN standard deviation values (SFNSDV).

$$SFNSDV_j=\sqrt{\frac{1}{m-1}\sum_{i=1}^{m}\left(\chi\left(NCC_{ij}\right)-\delta\left(NCC_j\right)\right)^2} \quad (18)$$

(3) Implement the attribute weight values.

$$c\omega_j=\frac{SFNSDV_j\sum_{t=1}^{n}\left(1-SFNCC_{jt}\right)}{\sum_{j=1}^{n}\left(SFNSDV_j\sum_{t=1}^{n}\left(1-SFNCC_{jt}\right)\right)} \quad (19)$$

Step 6. Implement the SFN positive distance information from average (SFNPDIA) and SFN negative distance information from average (SFNNDIA). For positive attributes (20) and (21), as shown at the bottom of the next page.

For negative decision attributes (22) and (23), as shown at the bottom of the next page.

Step 7. Implement the weighted SFNPDIA and SFNNDIA.

$$WSFNPDIA_i=\sum_{j=1}^{n}c\omega_j\times SFNPDIA_{ij} \quad i=1,2,\cdots,m \quad (24)$$

$$WSFNNDIA_i=\sum_{j=1}^{n}c\omega_j\times SFNNDIA_{ij} \quad i=1,2,\cdots,m \quad (25)$$

$$CC^{(k)}=\left[CC_{ij}^{(k)}\right]_{m\times n}=\begin{bmatrix}CC_{11}^{(k)} & CC_{12}^{(k)} & \ldots & CC_{1n}^{(k)}\\ CC_{21}^{(k)} & CC_{22}^{(k)} & \ldots & CC_{2n}^{(k)}\\ \vdots & \vdots & \vdots & \vdots\\ CC_{m1}^{(k)} & CC_{m2}^{(k)} & \ldots & CC_{mn}^{(k)}\end{bmatrix} \quad (7)$$

$$CC=\left[CC_{ij}\right]_{m\times n}=\begin{bmatrix}CC_{11} & CC_{12} & \ldots & CC_{1n}\\ CC_{21} & CC_{22} & \ldots & CC_{2n}\\ \vdots & \vdots & \vdots & \vdots\\ CC_{m1} & CC_{m2} & \ldots & CC_{mn}\end{bmatrix} \quad (8)$$

$$CC_{ij}=\left(CT_{ij}^{(k)},CI_{ij}^{(k)},CF_{ij}^{(k)}\right)=\left(\begin{array}{c}\sqrt{1-\prod_{k=1}^{l}\left(1-\left(CT_{ij}^{(k)}\right)^2\right)^{c\omega_j}},\\ \sqrt{\prod_{j=1}^{n}\left(1-\left(CT_{ij}^{(k)}\right)^2\right)^{cw_k}-\prod_{j=1}^{n}\left(1-\left(CT_{ij}^{(k)}\right)^2-\left(CI_{ij}^{(k)}\right)^2\right)^{cw_k}},\\ \prod_{k=1}^{l}\left(\left(CF_{ij}^{(k)}\right)^2\right)^{cw_k}\end{array}\right) \quad (9)$$

$$SFNCC_{jt}=\frac{\sum_{i=1}^{m}\left(\chi\left(NCC_{ij}\right)-\chi\left(NCC_j\right)\right)\left(\chi\left(NCC_{it}\right)-\chi\left(NCC_t\right)\right)}{\sqrt{\sum_{i=1}^{m}\left(\chi\left(NCC_{ij}\right)-\chi\left(NCC_j\right)\right)^2}\sqrt{\sum_{i=1}^{m}\left(\chi\left(NCC_{it}\right)-\chi\left(NCC_t\right)\right)^2}},\quad j,t=1,2,\ldots,n, \quad (17)$$

Step 8. Implement the normalized $WSFNPDIA_i$ and $WSFNNDIA_i$:

$$NWSFNPDIA_i = \frac{WSFNPDIA_i}{\max_i (WSFNPDIA_i)} \tag{26}$$

$$NWSFNNDIA_i = 1 - \frac{WSFNNDIA_i}{\max_i (WSFNNDIA_i)} \tag{27}$$

Step 9. Implement the SFN appraisal information (SFNAI) based on the $NWSFNPDIA_i$ and $NWSFNNDIA_i$.

$$SFNAI_i = \frac{1}{2}(NWSFNPDIA_i + NWSFNNDIA_i) \quad i = 1, 2, \cdots, m \tag{28}$$

Step 10. In line with $SFNAI_i$, rank and choose the optimal decision alternative.

IV. EMPIRICAL EXAMPLE AND COMPARATIVE ANALYSIS

A. AN EMPIRICAL EXAMPLE FOR DIGITAL TRANSFORMATION IN RETAIL ENTERPRISES

Green buildings fully embody the concept of sustainable development in architecture, and green building technology and economic evaluation are one of the most fundamental and crucial tasks in promoting green buildings [57], [58]. Through effective economic evaluation, it is possible to select the most suitable technical scheme among the new technical schemes of green buildings, effectively control the project cost, further improve the economic benefits of project investment, and also provide practical guidance and reference for similar project construction [59], [60]. The so-called green building technology and economic evaluation mainly refers to the detailed analysis and evaluation of the technical feasibility, economy, and other aspects of setting different plans, while referring to the obtained evaluation results to determine the final technical plan [57], [58], [59], [60]. In the operation process of green building projects, evaluation should be carried out from both technical and economic perspectives. However, at present, the evaluation of green building technology and economic evaluation is more focemployed on the overall level. Although this concept can to some extent meet the current needs for promoting green buildings and facilitate owners to identify the advantages of green buildings, from a specific work perspective, this approach is relatively one-sided and easy to create a certain illusion for people [61], [62]. At the same time, it also allows for the creation of conditions for different violations, which is unfavorable for promoting the development of the entire industry. In response to this, the actual connotation of green building technology and economic evaluation elaborated in the article is that technology and economic evaluation should be carried out together, and both exist and complement each other, jointly forming the decision-making basis for the plan. From another perspective, the economic evaluation of green building technology solutions should be conducted from a micro level, with the fundamental purpose of using standardized techniques and procedures to conduct technical and economic evaluations of different sub technologies (including energy-saving walls, energy-saving doors and windows, reclaimed water recovery, ground source heat pumps, etc.), in order to effectively classify them, This enables the selection of cost-effective technical solutions while ensuring sufficient funding [63], [64]. The overall technical and economic evaluation of green buildings focuses more on the macro aspect, which can strengthen the overall control. In the evaluation process of key technologies and economy, the overall green situation of green buildings is evaluated by referring to various information materials of green buildings. At the same time, it is compared and analyzed with the green needs and investment control of the construction unit. This can provide reference and suggestions for the comparison and selection of different technical solutions. Therefore, it is necessary to compare and analyze the required solutions of the construction unit from macro and micro perspectives, in order to select a cost-effective and feasible technical solution [65]. The green building

$$SFNPDIA_{ij} = \frac{1}{2}\left(\begin{array}{l}\frac{\max(0, SFNCSM(NCC_{ij}, SFNPIDS_j) - SFNCSM(SFNADS_j, SFNPIDS_j))}{SFNCSM(SFNADS_j, SFNPIDS_j)} \\ + \frac{\max(0, SFNED(NCC_{ij}, SFNNIDS_j) - SFNED(SFNADS_j, SFNNIDS_j))}{SFNED(SFNADS_j, SFNNIDS_j)}\end{array}\right) \tag{20}$$

$$SFNNDIA_{ij} = \frac{1}{2}\left(\begin{array}{l}\frac{\max(0, SFNCSM(SFNADS_j, SFNPIDS_j) - SFNCSM(NCC_{ij}, SFNPIDS_j))}{SFNCSM(SFNADS_j, SFNPIDS_j)} \\ + \frac{\max(0, SFNED(SFNADS_j, SFNNIDS_j) - SFNED(NCC_{ij}, SFNNIDS_j))}{SFNED(SFNADS_j, SFNNIDS_j)}\end{array}\right) \tag{21}$$

$$SFNPDIA_{ij} = \frac{1}{2}\left(\begin{array}{l}\frac{\max(0, SFNCSM(SFNADS_j, SFNPIDS_j) - SFNCSM(NCC_{ij}, SFNPIDS_j))}{SFNCSM(SFNADS_j, SFNPIDS_j)} \\ + \frac{\max(0, SFNED(SFNADS_j, SFNNIDS_j) - SFNED(NCC_{ij}, SFNNIDS_j))}{SFNED(SFNADS_j, SFNNIDS_j)}\end{array}\right) \tag{22}$$

$$SFNNDIA_{ij} = \frac{1}{2}\left(\begin{array}{l}\frac{\max(0, SFNCSM(NCC_{ij}, SFNPIDS_j) - SFNCSM(SFNADS_j, SFNPIDS_j))}{SFNCSM(SFNADS_j, SFNPIDS_j)} \\ + \frac{\max(0, SFNED(NCC_{ij}, SFNNIDS_j) - SFNED(SFNADS_j, SFNNIDS_j))}{SFNED(SFNADS_j, SFNNIDS_j)}\end{array}\right) \tag{23}$$

TABLE 1. Linguistic scale and SFNs [34].

Linguistic Terms	SFNs
Exceedingly Terrible-CET	(0.9,0.1,0.1)
Very Terrible-CVT	(0.7,0.3,0.3)
Terrible-CT	(0.6,0.4,0.4)
Medium-CM	(0.5,0.5,0.5)
Well-CW	(0.4,0.4,0.6)
Very Well-CVW	(0.3,0.3,0.7)
Exceedingly Well-CEW	(0.1,0.1,0.9)

TABLE 2. Evaluation values by CD_1.

	CG_1	CG_2	CG_3	CG_4
CA_1	CM	CT	CVW	CW
CA_2	CVT	CM	CVW	CT
CA_3	CT	CW	CM	CVW
CA_4	CVW	CW	CVT	CM
CA_5	CM	CW	CVT	CVW

TABLE 3. Evaluation values by CD_2.

	CG_1	CG_2	CG_3	CG_4
CA_1	CM	CT	CVW	CW
CA_2	CW	CVW	CVT	CT
CA_3	CM	CW	CT	CM
CA_4	CW	CVW	CT	CM
CA_5	CVT	CVT	CM	CW

technology schemes evaluation is the MAGDM issue. In this section, a numerical example for green building technology schemes evaluation is implemented through employing SFN-EDAS technique. So scientific green building technology schemes evaluation is of great decision significance. In order to construct the most optimal retail enterprises, some decision department sincerely invite three experts $CD = (CD_1, CD_2, CD_3)$ to evaluate the five green building technology schemes CA_i $(i = 1, 2, 3, 4, 5)$ through sincerely considering four attributes: CG_1 is the outdoor environment of green building, CG_2 is the technology advancement of green building, CG_3 is the annual operating cost of green building, CG_4 is the owner acceptance of green building, The CG_3 is cost type. $cw = (0.3346, 0.3233, 0.3421)^T$

TABLE 4. Evaluation values by CD_3.

	CG1	CG2	CG3	CG4
CA1	CW	CVW	CVT	CM
CA2	CVT	CVW	CM	CVT
CA3	CVW	CVT	CM	CT
CA4	CW	CM	CVT	CVW
CA5	CM	CT	CVW	CW

TABLE 5. The overall SFNs.

	CG1	CG2
CA1	(0.5451, 0.3879, 0.3768)	(0.6537, 0.3459, 0.3987)
CA2	(0.3812, 0.4238, 0.5756)	(0.3879, 0.4487, 0.5324)
CA3	(0.2358, 0.2982, 0.5139)	(0.5659, 0.3145, 0.3786)
CA4	(0.3765, 0.2387, 0.5746)	(0.3583, 0.4768, 0.5518)
CA5	(0.3465, 0.2198, 0.5649)	(0.2687, 0.1181, 0.5643)
	CG3	**CG4**
CA1	(0.4847, 0.1798, 0.3997)	(0.4547, 0.1924, 0.3694)
CA2	(0.4436, 0.1769, 0.2545)	(0.4518, 0.2527, 0.2675)
CA3	(0.3272, 0.2615, 0.4132)	(0.4426, 0.2837, 0.3546)
CA4	(0.4878, 0.3657, 0.4387)	(0.3823, 0.1234, 0.4215)
CA5	(0.3928, 0.1576, 0.4564)	(0.4283, 0.1876, 0.4435)

are experts weight values. The decision information from $CD = (CD_1, CD_2, CD_3)$ with linguistic scale values (See Table 1) are implemented in Table 2-4. Then the SFN-EDAS technique is employed to implement the green building technology schemes evaluation.

Step 1. Implement the group SFN-matrix $CC^{(k)} = \left(CC_{ij}^{(k)}\right)_{5\times 4}$ $(k = 1, 2, 3)$ as in Table 2-4. The SFN-matrix is derived through utilizing SFNWA technique. The results are implemented in Table 5.

Step 2. Normalize $CC = \left[CC_{ij}\right]_{5\times 4}$ to $NCC = \left[NCC_{ij}\right]_{5\times 4}$ (See Table 6).

Step 3. Obtain the SFNADS (Table 7).

Step 4. Obtain the SFNPIDS and SFNNIDS (Table 8).

Step 5. Implement the attribute weight information (Table 9).

TABLE 6. The normalized SFNs.

	CG_1	CG_2
CA_1	(0.5451, 0.3879, 0.3768)	(0.6537, 0.3459, 0.3987)
CA_2	(0.3812, 0.4238, 0.5756)	(0.3879, 0.4487, 0.5324)
CA_3	(0.2358, 0.2982, 0.5139)	(0.5659, 0.3145, 0.3786)
CA_4	(0.3765, 0.2387, 0.5746)	(0.3583, 0.4768, 0.5518)
CA_5	(0.3465, 0.2198, 0.5649)	(0.2687, 0.1181, 0.5643)
	CG_3	CG_4
CA_1	(0.3997, 0.1798, 0.4847)	(0.4547, 0.1924, 0.3694)
CA_2	(0.2545, 0.1769, 0.4436)	(0.4518, 0.2527, 0.2675)
CA_3	(0.4132, 0.2615, 0.3272)	(0.4426, 0.2837, 0.3546)
CA_4	(0.4387, 0.3657, 0.4878)	(0.3823, 0.1234, 0.4215)
CA_5	(0.4564, 0.1576, 0.3928)	(0.4283, 0.1876, 0.4435)

TABLE 7. The SFNDS.

	SFNADS
CG_1	(0.4098,0.3594,0.4102)
CG_2	(0.3105,0.3658,0.2895)
CG_3	(0.2643,0.3324,0.1413)
CG_4	(0.3415,0.3519,0.3216)

Step 6. Implement the SFNPDIA and SFNNDIA (See Table 10-11).

Step 7. Implement the WSFNPDIA and WSFNNDIA (See Table 12).

Step 8. Implement the NWSFNPDIA and NWSFNNDIA (Table 13).

Step 9. Calculate the SFNAI (See Table 14).

Step 10. In line with SFNAI, the order is: $CA_1 > CA_4 > CA_3 > CA_5 > CA_2$ and CA_1 is the optimal green building technology schemes.

B. COMPARE ANALYSIS

The SFN-EDAS technique is compared with the SFNWA technique [34], SFNWG technique [34], Spherical fuzzy

TABLE 8. The SFNPIDS and SFNNIDS.

	SFNPIDS	SFNNIDS
CG_1	(0.5451, 0.3879, 0.3768)	(0.2358, 0.2982, 0.5139)
CG_2	(0.6537, 0.3459, 0.3987)	(0.2687, 0.1181, 0.5643)
CG_3	(0.4564, 0.1576, 0.3928)	(0.2545, 0.1769, 0.4436)
CG_4	(0.4547, 0.1924, 0.3694)	(0.3823, 0.1234, 0.4215)

TABLE 9. The attributes weight.

	CG_1	CG_2	CG_3	CG_4
weight	0.2411	0.2832	0.2900	0.1857

TABLE 10. The SFNPDIA.

	CG_1	CG_2	CG_3	CG_4
CA_1	0.2928	0.5070	0.0000	0.4788
CA_2	0.0000	0.0000	0.3175	0.0000
CA_3	0.4436	0.0000	0.2049	0.0888
CA_4	0.5024	0.4964	0.0000	0.2214
CA_5	0.0000	0.0000	0.5385	0.0000

power WA (SFPWA) [66], Spherical fuzzy power WG (SFPWG) technique [66] and SFN-GRA technique [68]. Then, the order of different techniques is implemented in Table 15.

In line with Table 15, it is known that these techniques' order is slightly different, however, these techniques have same best green building technology scheme CA_1 and same worst green building technology scheme CA_2. In other words, all these techniques could effectively cope with the MAGDM issues through different research angles.

V. CONCLUSION

In recent years, people have paid more attention to energy conservation in production and life, and vigorously promoted the sustainable development of various industries. The construction industry is a highly energy consuming industry and has become one of the important industries implementing the concept of sustainable development. In response to this, the concept of green building has been widely applied, and in-depth exploration has been conducted in green building technology and economic evaluation. The article mainly takes a certain project as an example to explain the specific application of economic evaluation in the selection of green building technology solutions, hoping to be helpful to relevant professionals and have reference significance for promoting the development of green buildings. The green building technology schemes evaluation was a MAGDM. In this work, the SFN-EDAS technique based on SFNCSM

TABLE 11. The SFNNDIA.

	CG_1	CG_2	CG_3	CG_4
CA_1	0.0000	0.0000	0.0000	0.0000
CA_2	0.6207	0.0307	0.0357	0.0794
CA_3	0.0000	0.0769	0.0000	0.0000
CA_4	0.0000	0.0000	0.1716	0.0000
CA_5	0.2327	0.0824	0.0000	0.0321

TABLE 12. The WSFNPDIA and WSFNNDIA.

	WSFNPDIA	WSFNNDIA
CA_1	0.3031	0.0000
CA_2	0.0921	0.1835
CA_3	0.1828	0.0218
CA_4	0.3028	0.0498
CA_5	0.1562	0.0854

TABLE 13. The NWSFNPDIA and NWSFNNDIA.

	NWSFNPDIA	NWSFNNDIA
CA_1	1.0000	1.0000
CA_2	0.3037	0.0000
CA_3	0.6032	0.8813
CA_4	0.9990	0.7288
CA_5	0.5152	0.5345

and SFNED is implemented for managing the MAGDM. The CRITIC technique is extended to SFSs to implement the attribute weights based on SFNCSM and SFNED. Finally, an numerical example for green building technology schemes

TABLE 14. The SFNI.

	SFNI	Order
CA_1	1.0000	1
CA_2	0.1519	5
CA_3	0.7422	3
CA_4	0.8639	2
CA_5	0.5249	4

TABLE 15. Order of these different techniques.

Techniques	Order	The optimal choice	The worst choice
SFNWA technique[34]	$CA_1 > CA_4 > CA_3 > CA_5 > CA_2$	CA_1	CA_2
SFNWG technique[34]	$CA_1 > CA_4 > CA_3 > CA_5 > CA_2$	CA_1	CA_2
SFPWA technique [67]	$CA_1 > CA_4 > CA_3 > CA_5 > CA_2$	CA_1	CA_2
SFPWG technique [67]	$CA_1 > CA_4 > CA_3 > CA_5 > CA_2$	CA_1	CA_2
SFN-GRA technique [69]	$CA_1 > CA_4 > CA_3 > CA_5 > CA_2$	CA_1	CA_2
The proposed SFN-EDAS technique	$CA_1 > CA_4 > CA_3 > CA_5 > CA_2$	CA_1	CA_2

evaluation is implemented to show the superiority of SFN-EDAS. Therefore, the highlights of this work are outlined: (1) the CRITIC technique is employed to implement the attribute weight values based on SFNCSM and SFNED; (2) the EDAS technique is expanded to SFSs based on SFNCSM and SFNED; (3) a novel SFN-EDAS technique based on SFNCSM and SFNED is implemented for MAGDM; (4) an empirical example for green building technology schemes evaluation and some comparative analysis is implemented to verify the SFN-EDAS technique.

There are two research limitations in this article: firstly, the research data is based on a limited sample of green building technology companies, and the sample selection is limited, which may affect the applicability and universality of the theory. In the future, with data support, the scope and region of data selection should be expanded. Secondly, the study fully focuses on the moderating effect of dynamic competitive environment on dual innovation. However, market environmental factors are widespread, and future research work should focus on other regulatory factors, such as information technological turbulence, competitive pressure, and government management support.

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QIAN LI was born in Jiuquan, Gansu, China, in 1983. She received the master's degree from Sichuan University, China. She is currently with the Chengdu Jincheng College. Her main research interests include engineering management and construction technology.

YING LI was born in Jilin City, Jilin, China, in 1987. She received the master's degree from Sichuan University, China. She is currently with the Chengdu Jincheng College. Her main research interests include engineering management and engineering economics.